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82nd Report of the State Geologist 1989-90

CALIFORNIA
DEPARTMENT
OF CONSERVATION
Division of Mines and Geology

STATE OF CALIFORNIA
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EDWARD G. HEIDIG, Director

DIVISION OF MINES AND GEOLOGY
JAMES F. DAVIS
STATE GEOLOGIST

Cover Photo: Damaged house near Boulder Creek, Santa Cruz County. Rear of the houses are undermined by landslide during the Loma Prieta earthquake. *(Photo from Earthquake Engineering Research Institute.)*

82nd Report of the State Geologist

1989-90

California Department of Conservation
DIVISION OF MINES AND GEOLOGY
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Sacramento, CA 95814

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Geologists examining underground workings of the Sixteen-to-one gold mine, Alleghany Mining district, Sierra County. *Photo by J.G. Scarborough (1990).*

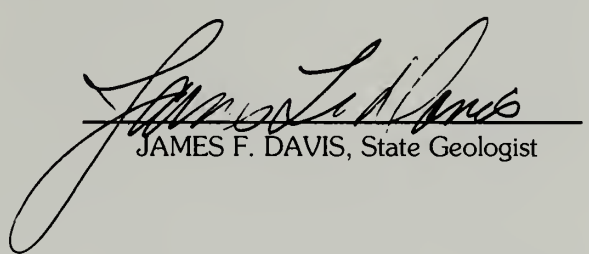
The Sixteen-to-one gold mine is located in the historic Alleghany Mining District of Sierra County. The mine is a classic high-grade Mother Lode gold mine. Gold mining at Alleghany began in 1852, expanded with time, and continued throughout World War II. It is famous for million-dollar gold "pockets," and has produced several high-grade pockets, each containing more than 10,000 troy ounces of gold. An effort is currently under way to redevelop the mine by employing state-of-the-art technology to systematically locate hidden high-grade pockets.

FOREWORD

The Department of Conservation's Division of Mines and Geology (DMG) is continuing to emphasize outreach through its products and advisory services. The 82nd Report of the State Geologist summarizes the assistance provided by DMG to State and local governments and to the public following the October 17, 1989 Loma Prieta earthquake.

The efforts of the Division to acquire and evaluate feedback from users of its reports and maps prepared by the Landslide Hazard Identification and Alquist-Priolo Special Studies Zone Projects are presented here. This feedback is used to increase the effectiveness of these activities.

The 82nd Report summarizes the Mineral Resource Development Program's automation and upgrading of the DMG mineral information files and the improvement of its geochemical capabilities. These efforts provide enhanced services to industry, State and local agencies, and to the public. The geochemical activities are also finding important applications to environmental health issues.



JAMES F. DAVIS, State Geologist

Seismologist explaining to visitors how the seismograph records earthquakes at DMG information display at State Capitol during 1990 State Scientist Day. *Photo by Max Flanery.*

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EXECUTIVE SUMMARY

During Fiscal Year 1989-90 the Division of Mines and Geology (DMG) actively responded to the Loma Prieta earthquake and expanded efforts to increase the effectiveness of the Division's Geologic Hazards and Mineral Resource Programs.

Loma Prieta Response:

DMG geologists were rapidly deployed to evaluate and map surface ruptures and earthquake-triggered landslides in the Santa Cruz Mountains. They advised local governments of their findings so high-risk occupancy of residences could be avoided. Nearly 100 DMG recordings of strong ground motion were processed and distributed rapidly to the engineering community, providing an understanding of the regional shaking patterns. Advice to the Governor's Office of Emergency Services included the interpretation of damage patterns and the probabilities of damaging aftershocks.

Landslide Hazard Identification Project (LHIP):

Effectiveness of DMG landslide hazard mapping was examined by DMG and the State Mining and Geology Board. Feedback indicates that local governments indeed need and use the map products and that the 2,000-feet-to-the-inch scale is appropriate. It was recommended that DMG be more aggressive in making users and the public aware of the project. New computer-based techniques were also recommended to process the landslide data.

Alquist-Priolo Fault Evaluation Project:

An independent review of the mapping of active faults under the Alquist-Priolo Special Studies Zone Act indicates that the maps are effectively providing the intended users with the intended information. It was suggested that more effort be placed on assuring compliance with the Act's requirement that buyers of properties in APSSZ areas be advised of their location.

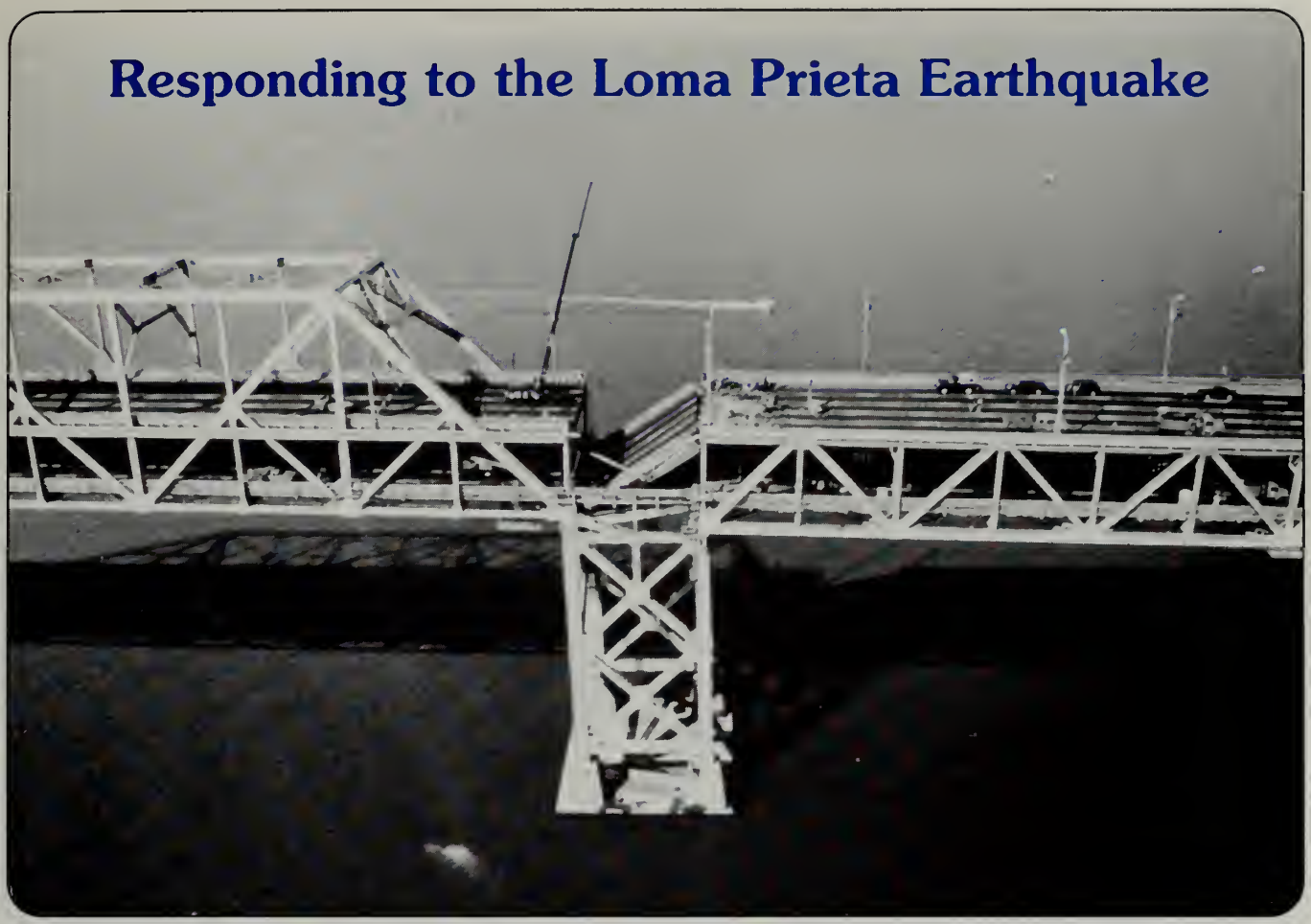
Applying Geochemical Capabilities:

DMG responds to requests for geochemical information concerning natural mineral substances in the environment that may have health implications. In 1989-90, DMG provided data about the distribution of asbestos minerals and means of identifying and determining their relative abundance to the State Mining and Geology Board and the Air Resources Board. DMG geochemical expertise can also help in dealing with health issues related to other natural mineral substances.

Organizing Information on Mineral Resources:

DMG is converting its paper files on California mines and mineral occurrences into a computer-based DMG system called MINEFILE. DMG also is working with the U.S. Bureau of Mines to merge the State and federal data bases for mines and prospects located in southern California. A merged data base will provide a valuable, conveniently accessible source of information which can be used in a variety of future land use decisions including federal legislation covering the disposition of public lands and local government consideration of land use permits.

Responding to the Loma Prieta Earthquake



Collapsed segment of the Bay Bridge that occurred during the Loma Prieta earthquake. *(Photo by E.V. Leyendecker.)*

At 5:04 p.m. on October 17, 1989, a magnitude (M) 7.1 earthquake occurred along a 23-mile segment of the San Andreas fault in the Santa Cruz Mountains. The Loma Prieta earthquake killed 63 people, injured 3,757 and caused 5.9 billion dollars in direct losses. It was the largest California earthquake since the Kern County event of 1952.

The responsibilities of the Division of Mines and Geology (DMG) include the rapid analysis of the geologic effects of damaging earthquakes and the provision of information to the Governor's Office of Emergency Services (OES), local governments, the media and the public. This account outlines the DMG responses to the Loma Prieta earthquake, both immediately after the event and in the following weeks and months.

A number of aspects of the Loma Prieta event distinguish it from other earthquakes along the San Andreas system. The depth of initial rupture was 11.5 miles, which is several miles deeper than most earthquakes on the San Andreas fault. There was no through-going rupture at the surface over the zone where movement occurred at depth. Horizontal movement of 3 to 6 feet along a vertical plane is typically expected for a M 7.1 event on the San Andreas fault. The Loma Prieta displacement involved a combination of 3.9 feet of vertical and 5.3 feet of horizontal offset on an inclined fracture surface. Because the fault ruptured from the middle of the failure zone towards each end, rather than beginning at one end, the resulting time span of the strong shaking was only about half of what would otherwise be expected. A seismogram recording of the Loma Prieta mainshock is shown in Figure 1.

Mapping Surface Ruptures

Under the auspices of the statewide Alquist-Priolo (A-P) Special Studies Zone Act, DMG geologists had mapped and zoned the active strands of the San Andreas fault at the surface years before the earthquake. This information assists local governments in regulating development within the A-P zones in order to avoid placement of structures on the active fault strands. DMG geologists went into the field immediately after the earthquake to check the accuracy and completeness of their previous mapping by investigating the new fractures along the fault. Instead of observing a set of through-going ruptures along the fault zone, the staff found a complex pattern of fissures without simple offset relationships. These unexpected features may be due both to the extraordinary vertical component of movement on the inclined fault plane and to landsliding of materials near the earth's surface.

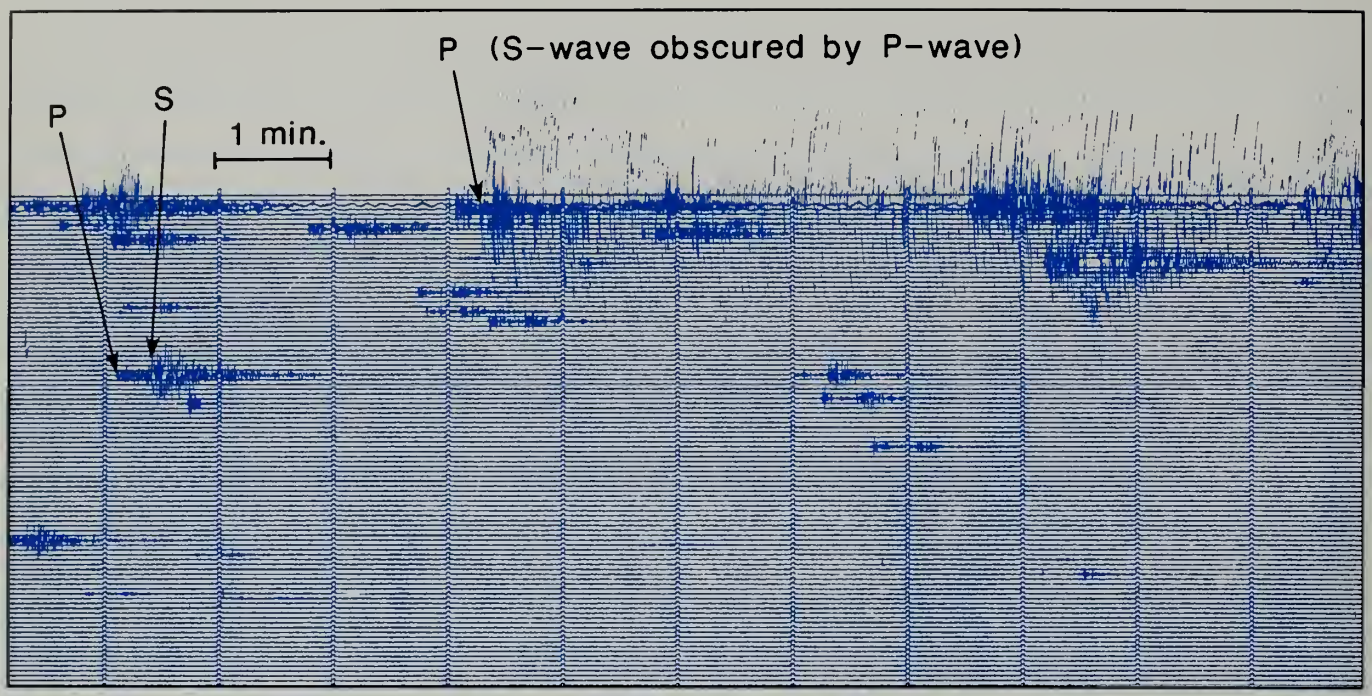


Figure 1. Seismogram of the Loma Prieta earthquake recorded by DMG instruments. The time difference between the arrival of the primary wave (P) and the secondary wave (S) helps locate the epicenter of the earthquake. The arrival time of the S-wave for the main shock is obscured by the P-wave.

It is important to understand the Loma Prieta rupture patterns and apply the resulting insights to any A-P zoning revisions that may be appropriate. In considering A-P zoning, the objective is to avoid placement of structures on rupture surfaces that may move during earthquakes. While many of the fissures could not be identified unambiguously as fault-related, they showed evidence of earlier movements as well as having been offset during the Loma Prieta event. It can be argued that features that have experienced repeated movements, such as those mapped after Loma Prieta, should be included within A-P zones even when the investigators are not certain that they are entirely fault-related. DMG is considering the policy implications of modifying the criteria for A-P zoning to accommodate circumstances like those associated with Loma Prieta.

Mapping Earthquake-Triggered Landslides

The Loma Prieta earthquake created new landslides and reactivated others. Landslides are pervasive throughout the Santa Cruz Mountains and constitute serious geologic hazards. Some have originated from the effects of gravity on weaker rocks and soils exposed on steep slopes. Other types have been induced by strong ground shaking associated with previous earthquakes. The hazard does not end with strong ground shaking. During periods of high precipitation, slide surfaces can become lubricated and gravity can cause further movement and damage.

DMG was requested by OES to map the most significant earthquake-triggered landslides in the stricken area. DMG was assisted by scientists from the U.S. Geological Survey and other groups. Fortunately, the earthquake occurred during the dry season following several years of low rainfall. DMG staff mapped the complex patterns of landslides and ambiguous fractures that may be fault-related. Large scale mapping of a 350,000 acre area in the epicentral region of the Santa Cruz Mountains identified localities where earthquake-triggered slides present ongoing hazards to public safety. The maps and the staff's advice were used by Santa Cruz County officials to determine where reoccupancy of damaged structures was considered safe, to locate landsliding where heavy rains might further endanger structures, and to delineate areas where special detailed landslide investigations should be required before future reconstruction or development takes place. In Santa Cruz and Santa Clara counties, DMG staff performed clearinghouse functions and posted the information on landslide damage received from the field investigators on wall maps.

Santa Cruz County applied to the Federal Emergency Management Agency for assistance in evaluating the potential for future movement on some of the landslides. A technical advisory group including scientists from DMG, the U.S. Geological Survey, the U.S. Army Corps of Engineers and other organizations was established. Several boreholes were drilled and instrumented with devices to measure water pressure along the subterranean slip surfaces so that changes in pressure can be used to evaluate the potential for further landslide movements. The group will continue this project during the winter of 1990-91.

The Loma Prieta experience has sharpened the Division's understanding of the services that it can provide to assist the OES and local governments in dealing with landslide hazards in the days and months that follow damaging earthquakes. This knowledge will be applied to improvement of DMG response plans.

Recording Intensities of Earthquake Shaking

DMG has installed almost 500 strong motion monitoring stations in the earthquake-prone portions of California to provide records of earthquake shaking for use in hazard reduction activities. Significant-sized earthquakes trigger those recording instruments that are near enough to the fault source to have had a preset threshold level of strong motion exceeded. The resulting records provide important data regarding the intensity and duration of the shaking as measured at stations located on the ground and within structures.

The staff of DMG's Strong Motion Instrument Program (SMIP) is organized to go into the field quickly after a triggering event to collect records and reset the equipment so that aftershocks can be monitored. Ninety-three DMG stations recorded the Loma Prieta event, and produced the largest set of data ever recorded from an M 7 earthquake. Records processing began immediately and provided information on the intensity of strong motion. These data were used to interpret how the pattern of shaking intensity relates to various distances from the fault source and to soil and rock conditions at the station sites. The conclusions were used by the engineering community shortly after the earthquake to interpret the relationship of recorded strong motion to the observed damage of different types of buildings. Such insights may be helpful in reaching the initial decisions about the degree of access that should be permitted to damaged structures. In the longer term, strong motion records are used to forecast the intensity of ground shaking associated with future earthquakes and to assess how various categories of construction will perform during shaking.

Landslide along highway in the epicentral area of the Loma Prieta earthquake. *(Photo from Earthquake Engineering Research Institute.)*

DMG published and distributed the processed acceleration and velocity data from the most significant records within 30 days of the earthquake as the program's operating procedures require.

The Governor's Board of Inquiry on the 1989 Loma Prieta Earthquake requested that the Division present summaries of the strong motion data. The DMG reports, which were submitted in December 1989 and February 1990, included ground motion observations near the sites of the collapse of portions of the Bay Bridge and the Cypress Section of the Interstate 880 Freeway as well as data on the nearby geologic conditions. These results were used by the Board of Inquiry in the development of its report that was presented to the Governor on June 1, 1990.

Loma Prieta created an unprecedented workload for the SMIP staff. The program requirements that SMIP provide rapid record retrieval, data analysis, publication and dissemination of the Loma Prieta results were successfully accomplished. Feedback regarding SMIP products and services has been positive.

Fissure in front of a house near Summit Road in Santa Cruz County. Geologists disagree whether these fissures are fault rupture or landsliding. *(Photo by C.J. Wills.)*

Providing Information to the Public

Following the earthquake, a Public Contact Office was established by the staff of the DMG's Geologic Information and Publications Project (GIPP). The main purpose of setting up a Public Contact Office after a significant geologic event, such as Loma Prieta, is to provide reliable geologic information to State and local emergency officials, to the news media, to earth science professionals, and to the public.

The Public Contact Office handled over 200 requests for information from news media, including radio, television and newspapers. In addition, several poster-type displays were made, and staff helped in preparing figures for publication. All of these activities were superimposed on existing deadlines and publication schedules.

A key element in all of these efforts was the verification of geological information and the assignment of incoming inquiries to the appropriate staff. GIPP served as the conduit for information, not as a primary source. Many DMG staff in A-P, the Landslide Hazards Identification Project and SMIP provided information to the Public Contact Office during the response.

Given these conditions, GIPP is reviewing its capability to provide the most effective information possible to the various user groups.

Advising OES at the Emergency Operations Center

The State Geologist advises the Director of OES on the validity of earthquake predictions and on other earth science public safety issues related to government policy. Shortly after 6 p.m. on October 17, 1989, the State Geologist and a Senior Seismologist joined the multi-agency team at the OES Emergency Operations Center (EOC) in Sacramento where OES provided information and coordinated aid to the Bay Area.

In June 1988 and August 1989, two M 5.2 events, known as the Lake Elsman earthquakes, occurred near the portion of the San Andreas fault that failed during Loma Prieta. The State Geologist advised OES that the Loma Prieta event was in the area where an advisory had been issued to local governments about the possibility of larger damaging events shortly after each of the Lake Elsman earthquakes. This provided a useful background for OES during its emergency communications with the local governments.

The potential for the occurrence of smaller, yet damaging aftershocks, and for follow-on events larger than the M 7.1 Loma Prieta earthquake needed to be presented in advisories to local governments as early as possible. The State Geologist conferred with scientists of the U.S. Geological Survey to develop a statement for OES to use. The conclusions in the statement were based on a recently developed statistical tech-

Geologist measuring displacement along ground fissure near Summit Road, Santa Cruz County. *(Photo by T.E. Spittler.)*

nique of the U.S. Geological Survey that analyzed the characteristics of the Loma Prieta aftershock sequence that had begun immediately after the earthquake. During the next two and one-half days, the State Geologist evaluated a succession of statistical updates on damaging earthquake probabilities as they were prepared by the U.S. Geological Survey technique.

DMG had previously published two hypothetical scenarios of earthquake damage to lifeline structures, such as highway, electrical, water and communication systems resulting from events on the San Andreas and Hayward faults in the Bay Area. Incoming reports of damage to lifeline structures were compared with the scenarios. This helped interpret the context of reported damage in the first hours after the earthquake.

OES has indicated that participation of the State Geologist and the Senior Seismologist at the EOC was valuable and that plans for future EOC operations will continue to include this collaboration. After future large earthquakes, the most important insights that DMG can provide to OES at the EOC will include: characterizing the potential for damaging follow-on events; assisting in developing the geologic hazards descriptions for advisories to local governments; making insights available from DMG damage scenarios; and assisting in the interpretation of the significance of damage reports using a geologic context.

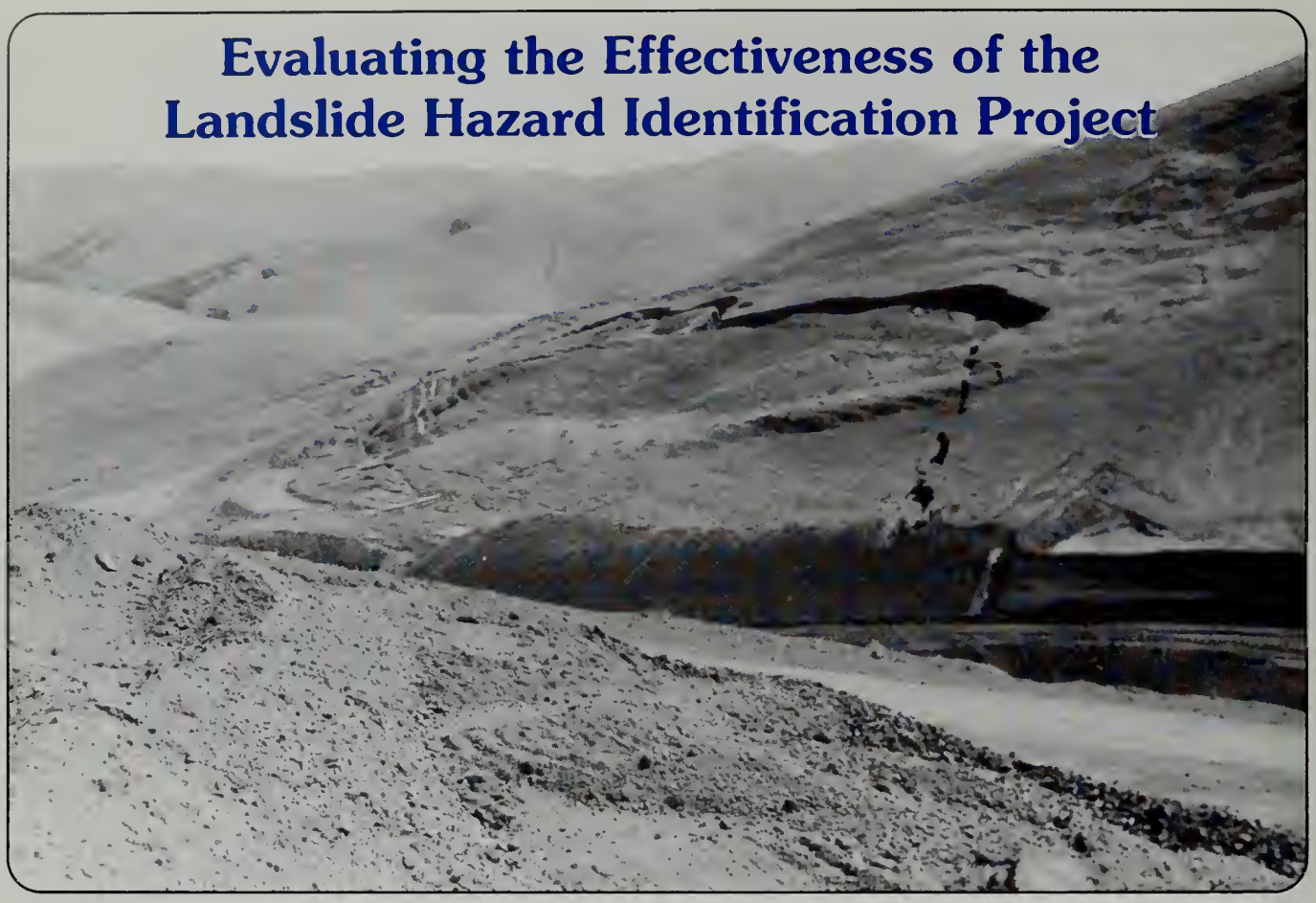
Future Implications of the DMG Response to Loma Prieta

The Division has a vital future role in the prompt collection of information about the effects of large earthquakes. The provision of technical advice to other State agencies and to local governments is critical to their wise management of emergency resources. Characterizing surface fault rupture, landslides and strong motion will continue to be prime DMG responsibilities. The experiences of Loma Prieta can increase the efficiency of organizing and prioritizing staff efforts, improving internal communications, and enhancing the effectiveness of DMG advice to other agencies.

The Loma Prieta earthquake also focused attention on a broad class of earthquake hazards issues, several of which have implications for future DMG programs. For example, DMG has published four planning scenarios for large earthquakes in the Los Angeles and San Francisco Bay areas. The Loma Prieta event did not occur at a scenario location, yet many effects were similar. This success invites consideration of whether more scenarios should be completed to cover more possible sources.

A second issue is the widespread damage caused by ground failures including liquefaction. At present, the A-P project maps active faults and designates Special Studies Zones surrounding them. Since many types of ground failure based on soil characteristics could be anticipated and mapped in advance, DMG is looking into the feasibility of extending the A-P concept to include various types of ground failure.

Evaluating the Effectiveness of the Landslide Hazard Identification Project



This landslide was reactivated during grading for a new subdivision in Sky Valley, near Vallejo in Solano County. The existing landslide had been mapped by the Landslide Hazards Investigations staff. *(Photo by M.W. Manson.)*

The Division is committed to evaluating the effectiveness of its projects and to using the insights from this process to improve future activities. The Landslide Hazard Identification Project (LHIP) has presented slope instability hazard information to local governments for over 6 years. It is important to get feedback from the staffs of local governments and from the geotechnical consultants who, as a group, include both local governments and developers among their clients. The DMG and the State Mining and Geology Board created an *ad hoc* committee to provide feedback on LHIP products and services. This discussion summarizes the committee's evaluation.

Landslide disasters during the past 20 years in California have killed nearly 100 people and caused hundreds of millions of dollars in property damage and other economic losses. The combination of recent landslide disasters during rainy years and the increasing rate of development of hillside terrains led to the State Legislature taking measures to assist local governments in the mitigation of landslide problems. Accordingly AB 101, the Landslide Hazard Identification Act, was passed in 1983.

The purpose of the LHIP, established by the Act, is to reduce landslide hazards and prevent or reduce property losses in developing areas. Losses are reduced by interaction between DMG and local governments that regulate development in landslide-prone areas.

LHIP geologists prepare packages of maps to assist local government agencies in their land-use and development permitting decisions. The maps depict existing landslides and areas subject to rapid moving debris flows and mudslides. They also display the DMG staff's interpretation of the relative susceptibility to landslide processes of all slopes within a mapped area. To date, map packages for more than 20 areas in a dozen California counties have been released as Open File Reports or are being prepared (Figure 2). The packages include a geologic map of the study area that presents basic information and a landslide susceptibility map that interprets the interactions between earth materials at the surface and slope conditions.

LANDSLIDE HAZARD IDENTIFICATION MAPS

Released as Open-File Reports through 1990 ●

1. Petaluma Dairy Belt
2. W/2 Newhall Quadrangle
3. Parts of Diablo and Dublin Quads.
4. Encinitas Quadrangle
5. E/2 Val Verde Quadrangle
6. Rancho Santa Fe Quadrangle
7. E/2 Newhall Quadrangle
8. Benecia/Vallejo Area
10. N/2 Oat Mountain Quadrangle
11. S/2 Fairfield Quadrangle
12. Puente/San Jose Hills Area
13. Cordelia/Vallejo Area
14. Vacaville and Vicinity
15. Lake Arrowhead/Big Bear Lake
16. Clear Lake and Vicinity
19. Cache Creek and Vicinity
20. N/2 Calabasas Quadrangle

Projects in progress or initiated in 1990 ▲

9. SE/4 Whitaker Peak Quadrangle
17. N/2 Black Star Canyon Quadrangle
18. Yucaipa/Forest Falls Quadrangles
21. Livermore Valley and Vicinity
22. Simi Valley Area
23. Weaverville and Vicinity
24. City of Ukiah
25. El Cajon Quadrangle and Vicinity
26. Moorpark/Santa Paula Quadrangles
27. Tassajara/Byron Hot Springs Quads.
28. Map of Earthquake-Generated Landslides, Santa Cruz Mountains

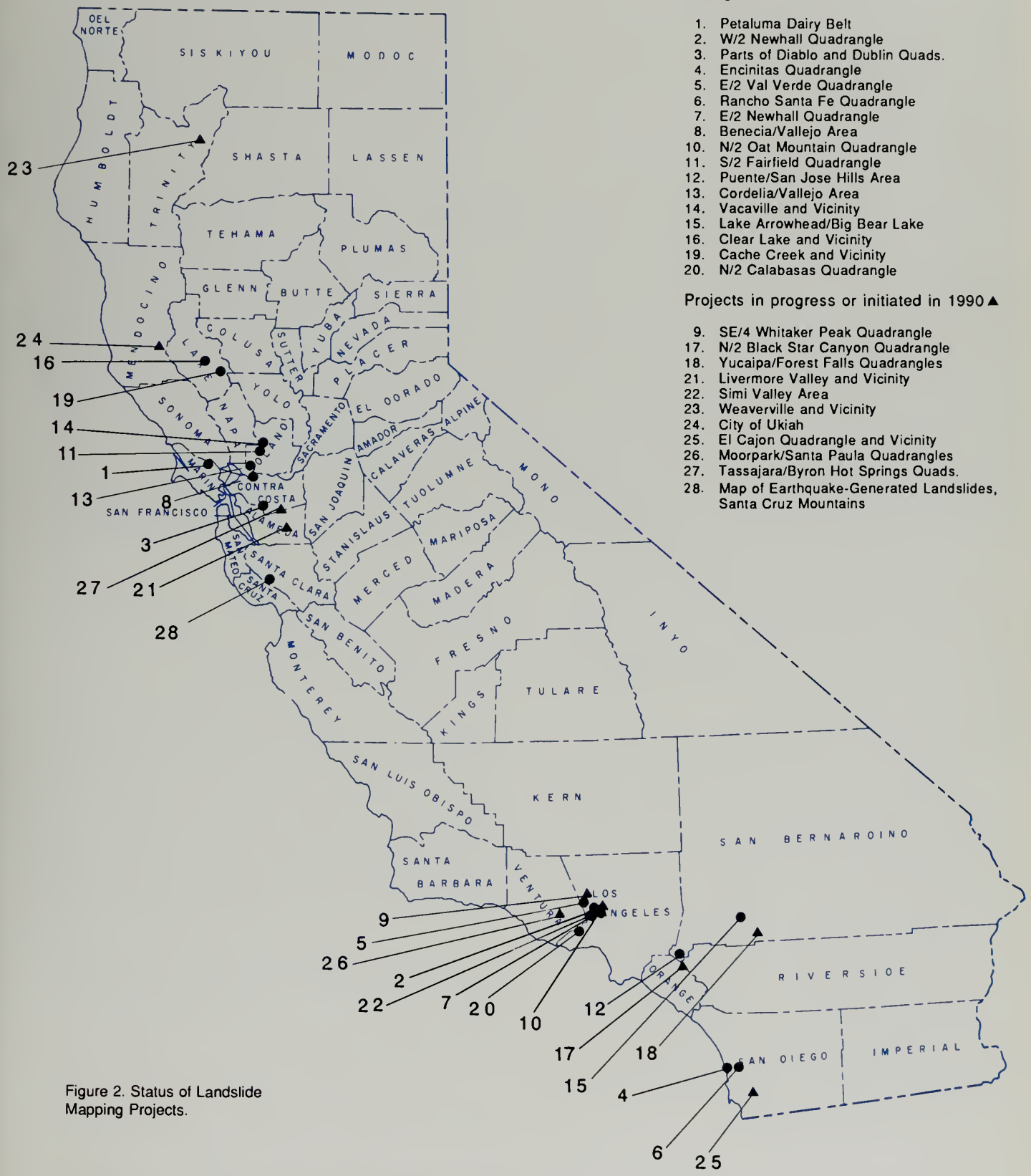
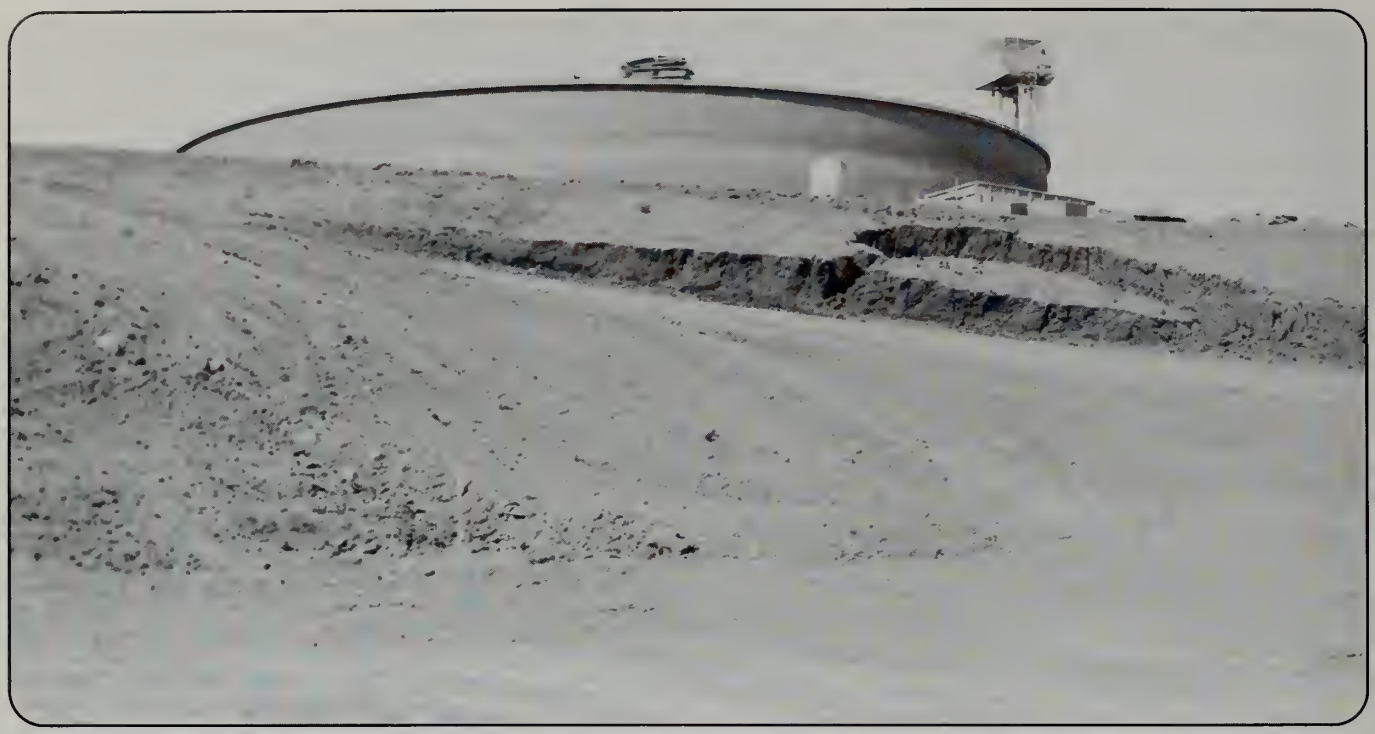


Figure 2. Status of Landslide Mapping Projects.



Landslide activated by grading in Sky Valley, near Vallejo in Solano County. This landslide is threatening a newly constructed water tank for a planned subdivision. This area was shown as landslide-prone on a DMG Landslide Hazards Investigation Project map. *(Photo by M.W. Manson.)*

In addition to preparing the maps, LHIP geologists meet with local officials during the mapping process and when the maps are published and released. The staff also provide timely advice following natural disasters. For example, the entire project staff were mobilized immediately following the October 17, 1989, Loma Prieta (Bay Area) earthquake, identifying and evaluating landslides and studying related geologic hazards in the area affected by the earthquake.

Findings of the *Ad Hoc* Advisory Committee

The Geohazards Committee of the State Mining and Geology Board and the DMG convened an *ad hoc* committee of local government planners, geologists and geotechnical experts from consulting firms and academia. Appropriate DMG staff provided input to the group.

The committee was to evaluate the LHIP map products and to recommend possible changes in mapping procedures, content, and scale. The committee's principal findings are summarized in the discussion that follows:

- *The Need for the Project:* In an advisory capacity to local governments responsible for land-use regulations, the Division must identify and call attention to landslide hazards. DMG is a nonregulatory, scientific agency that is regarded as objective and is the logical State unit to carry out this advisory role.

- *The Usefulness of the Types of Maps Provided:* The landslide hazard susceptibility maps can be understood by nontechnical government officials. Consulting geologists wish to continue receiving the geologic maps containing the basic field observations so they can determine the scientific evidence upon which the landslide susceptibility interpretations have been made by the DMG staff.

- *The Best Map Scale to Present Landslide Susceptibility Information:* The currently used scale of 1:24,000 (one inch equals 2,000 feet) is the most appropriate choice for landslide maps. This is the standard scale at which U.S. Geological Survey topographic maps are published. Planners also frequently work with a variety of data plotted at this scale. Developers can be required by local government to prepare more detailed maps at larger scales when they investigate the special construction requirements that may be necessary to build safely in areas with identified landslide hazards.

- *The Adequacy of DMG Communication of Information about Its Landslide Hazard Identification Studies:* Although maps are sent to the officials of jurisdictions for which the materials have been prepared, the efforts to publicize the maps should be increased. In addition, a booklet explaining how to use the maps is necessary.

Coastal cliff failure. The Crest Apartments, Depot Hill, Capitola.
Bedrock is the Purisima Formation siltstone. *(Photo by R.H. Sydnor.)*

Recommendations of the *Ad Hoc* Advisory Committee

The Division is implementing the recommendations of the advisory committee to the extent possible using existing resources.

- *Actions to Increase Public Awareness:* DMG should prepare a list of available landslide map sets. The list should be sent to all registered and certified geologists and engineering geologists on the State Board of Registration list and to the State Real Estate Board.

DMG landslide maps should be given more exposure in *California Geology*, DMG's monthly magazine.

- *Action to Increase Usefulness:* A "User's Guide" to help planners and others employ landslide maps in their activities should be prepared.

- *Increased Productivity:* Opportunities to improve the output of the landslide project should include application of Geographic Information System technology to achieve efficiency in map preparation and reproduction, and to allow release of data on computer disks for local agencies to incorporate into their own data bases.

Assessing the Effectiveness of the Alquist-Priolo Fault Evaluation and Zoning Project

Trench across the Raymond Hill fault for a subsurface investigation to verify the location of the fault. Such investigations are required for new construction in Special Studies Zones. *(Photo by Leroy Crandall and Associates.)*

The Alquist-Priolo Fault Evaluation and Zoning Project (A-P), is carried out under the Alquist-Priolo Special Studies Zones (APSSZ) Act of 1972. The Act mitigates the hazard of surface faulting by preventing the building of structures for human occupancy across the traces of active faults. The principal responsibility of the DMG under this Act is to delineate new and revised regulatory zones, known as Special Study Zones (SSZs), around active faults and to issue preliminary and official maps of the SSZs to cities, counties, and state agencies for review and implementation (see DMG Special Publication 42 for additional discussion of responsibilities). Figure 3 illustrates a portion of an Alquist-Priolo Special Studies Zone as it is represented on a standard U.S. Geological Survey 7.5 minute topographic base map. This is an example of the type of map information which is provided to local governments to assist them in earthquake hazard reduction.

In 1989, The Reitherman Company was commissioned to evaluate the effectiveness of A-P. The scope of the evaluation included the provisions of the APSSZ Act and associated regulations, DMG's fault mapping and zoning activities, local government compliance with the Act requirements and feedback from geologic consultants who use the maps in their practice.

Conclusions Regarding A-P Effectiveness

A questionnaire was sent to the planning directors, building officials, staff geologists, and emergency services coordinators for all 113 cities and counties affected by SSZs. Additional questionnaires were sent to consulting geologists, state agencies, real estate firms, and other users of the A-P products. Personal interviews were also conducted and the geologic literature relative to the program was reviewed. The principal conclusions of this study follow:

- *Overall, the program has been effective.* The main purpose of the APSSZ Act (mitigation of surface faulting hazard) has been well served through the use of A-P products and services by local governments and geologic consultants.

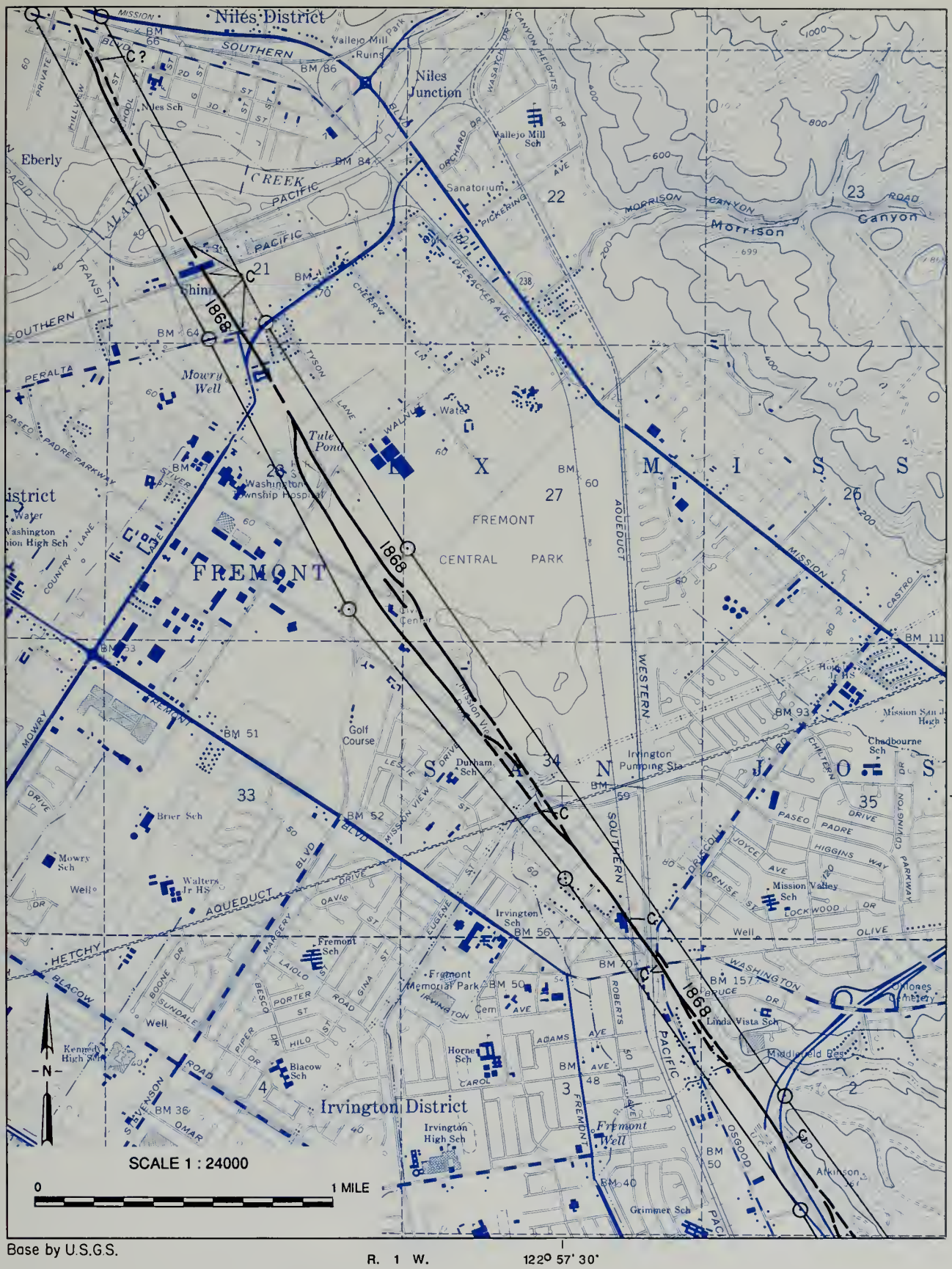


Figure 3. Part of the Special Studies Zone Map of the Niles quadrangle in Alameda County. Surface rupture occurred along this segment of the Hayward fault in 1868 and fault creep is occurring now. Site-specific investigations involving trenching as shown in the photo on page 10 have accurately located the surface trace of the Hayward fault and setbacks have been established (see photo on page 12).

Aerial photograph of a portion of the Hayward fault shown in Figure 3. A setback was established in the apartment complex in the center of the photograph so structures for human occupancy were not constructed across the fault.

• *The disclosure requirement is ineffective.* The provision of the Act which requires disclosures of the location of parcels within SSZs to buyers at the close of escrow is considered to be relatively ineffective.

• *DMG SSZ maps and other products have been very useful.* However, DMG SSZ maps and reports have not been publicized adequately.

• *The consultants' reports are satisfactory.* The reports of geologic investigations of subdivision sites which local government must require from developers within SSZs are adequate. The reviews of these reports are also satisfactory.

• *DMG A-P mapping should continue.* The evaluation concludes that the DMG must maintain the pace of its fault studies and zoning work to ensure the technical quality of the program. The recommendations for improving other aspects of the A-P (e.g., publicizing and disseminating information) should not diffuse the zoning work.

Recommendations

The 1990 effectiveness report presents the pros and cons of 62 policy issues and options identified in the survey. The 27 most promising options were selected as recommendations by the consultants for improving the A-P Act and program. The highlights of these recommendations are presented in the discussion that follows.

• *Increasing the Awareness of the A-P Products and Services:* Although local governments and geologic consultants are using A-P products, the high turnover of their personnel makes continuous publicizing of the project necessary. A number of important initiatives and new emphases are possible under the current APSSZ Act.

DMG should keep planners, building officials, geologic consultants and others up-to-date with lists of new maps and Fault Evaluation Reports. These parties should also be invited to participate in meetings and workshops where A-P products and services are described.

Courses for geologic consultants will improve the investi-gations of fault activity which are required by local governments within A-P zones.

New publications should include a revised set of guidelines for geologists to use in evaluating fault-rupture hazards, and another set to help local governments during their reviews of consultants' reports. A nontechnical brochure explaining the APSSZ Act and the significance of having property located within SSZs is also needed.

• *Increasing Compliance with the Purpose and Requirements of the APSSZ Act:* Incentives and assistance to increase compliance with the APSSZ Act will increase the effectiveness of DMG A-P activities.

Local governments and the public should be encouraged to report questionable practices by geologic consultants to the State Board of Registration for Geologists and Geophysicists. The success of the APSSZ Act depends heavily upon the quality of the consultants' reports. The Board of Registration for Geologists and Geophysicists should be more aggressive in the investigation of questionable consulting geologist practices.

The APSSZ Act should be modified to employ a revised, more effective disclosure statement, and to mandate the training of real estate personnel about the disclosure process. It should also be necessary that the disclosure statement, after being signed by all parties, be filed by local government with the deed for the property.

• *Expansion of the Scope of the APSSZ Act to Further Reduce Earthquake Losses:* Based upon A-P experience, recommendations were made to broaden the use of the A-P approach.

Legislation similar to the APSSZ Act should require mapping of the potential for earthquake-induced landslides, liquefaction and other forms of ground failure in "Seismic Hazard Special Study Zones." Within the zones, local governments should require developers to submit geologic consultants' reports which analyze how construction should be designed to achieve seismic safety.

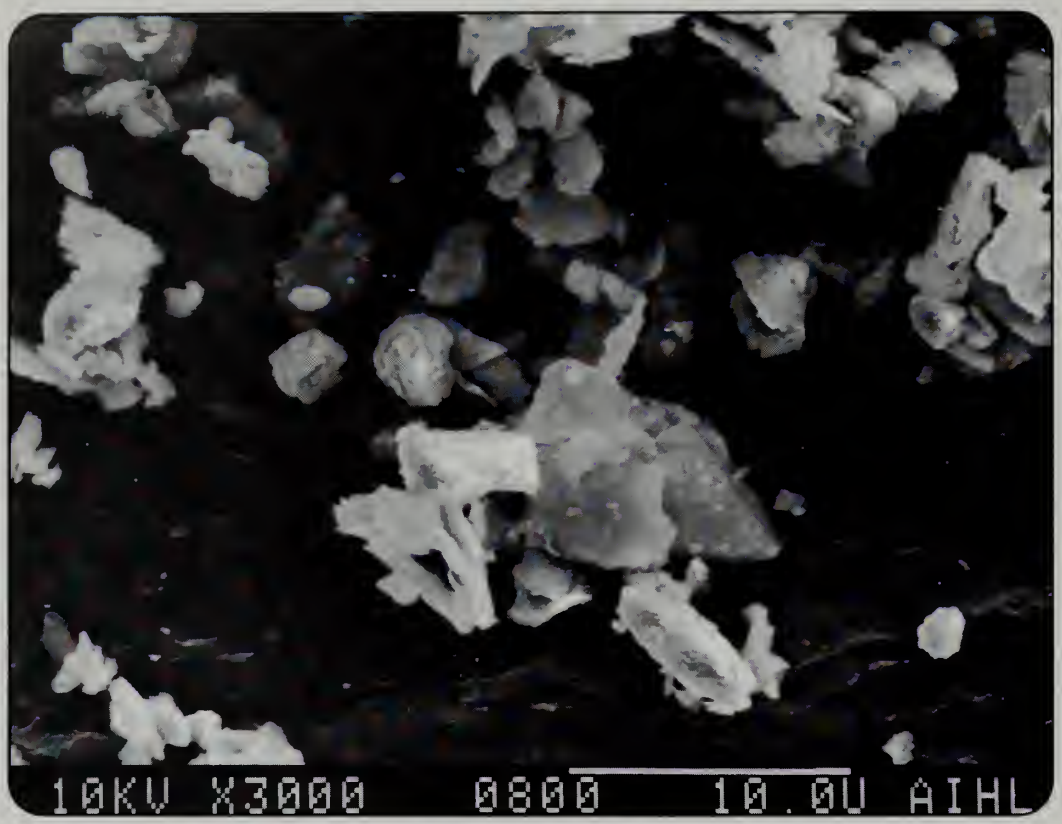
The APSSZ Act should be modified to require special studies to be submitted prior to building critical lifelines (e.g., transportation and communications) and facilities containing hazardous wastes. Presently the Act is only directed to buildings for human occupancy.

A-P Plans for Implementing the Recommendations of the Consulting Report

Because of present staffing and budgetary limitations, it is possible to implement only some of the recommendations. Several are already being partly implemented and others will be initiated in the near or intermediate future (e.g., releasing of unpublished file data and publicizing A-P products). Other recommendations can only be accomplished by collaboration with other agencies, by increases in A-P funding or by changes in the law or regulations.

Currently DMG is developing plans to accommodate the large backlog of faults that need to be evaluated for possible new or revised zoning. Under Section 2622 of the Act, the State Geologist is required to issue new and revised SSZ maps when warranted by new information. Zoning is necessarily an ongoing function of the project, a fact which has been recognized by the effectiveness study.

Applying New DMG Geochemical Capabilities to Mineral Resource Investigations and to Environmental Health Issues



Photograph of submicroscopic silica particles. These particles are probably crystalline quartz. Magnified 3000 times. *(Photo by W. John, Department of Health Services.)*

DMG established an in-house geochemical analysis facility in Fiscal Year 1989-90 to support mineral resource investigations carried out under the auspices of the Surface Mining and Reclamation Act (SMARA). These services improve the quality of mineral commodity and mineral land classification reports and mineral resources maps. Besides sample analyses, this new facility provides mineralogical and geochemical data interpretations to assist DMG investigators. Information is also being provided to Air Resources Board personnel and to the State Mining and Geology Board on the geochemical aspects of several environmental health concerns including asbestos and crystalline silica.

DMG Geochemical Capabilities

DMG requirements for in-house geochemical analyses are changing. Whole rock chemical analyses which determine the amounts of major and trace elements present in samples (e.g., the percentages of iron, copper, aluminum, etc.) were formerly done within DMG, but are now obtained from commercial laboratories. Advances in analytical techniques during the last ten years now allow commercial laboratories to provide low cost, high quality, whole rock analyses with quick turnaround times. Because the current number of requests for this type of analysis is relatively small, and DMG's equipment, space, and staff are limited, it is most cost-effective to contract for this analytical and assay work. The analyses of DMG samples performed by the commercial laboratories are monitored by the DMG geochemist to assure quality control.

Identification of minerals and description of their physical characteristics are now the principal emphases of the geochemistry facility. The SMARA staff employ this information in their evaluation of the future usefulness of mineral deposits. Staff needs for physical descriptions and mineral identifications are more effectively met in-house where there can be close interaction between the geochemist and the geologist. The DMG geochemical facility identifies the minerals—naturally occurring chemical compounds, (e.g., calcium carbonate [calcite] and silicon dioxide [quartz]) which compose the rocks. The DMG lab uses an X-ray beam to identify the minerals. X-ray diffraction can also determine the percentages of different minerals in a rock. In the nine months of operation of the

new automated X-ray diffractometer (from early October, 1989, through June, 1990), 445 samples have been analyzed. The number is expected to increase significantly in 1990-91.

Understanding the sizes and shapes of the mineral grains that make up specimens collected in the field is also important to SMARA investigations. The DMG geochemical facility can provide these descriptions of the physical characteristics by examination using an optical microscope and other methods.

Arrangements have been made with the Geology Department and the Facility for Advanced Instrumentation at the University of California, Davis, for DMG to have access to an electron microprobe and the scanning electron microscope equipment for DMG mineral studies. The probe provides chemical analyses of individual mineral grains and the electron microscope produces high magnification imaging. These techniques complement in-house analyses made by DMG and permit a thorough chemical and physical characterization of mineral deposit samples.

Contributions to Mineral Resource Investigations

The geochemical analysis of rock, mineral and soil samples provides information for project geologists to use in determining whether the deposits they are investigating are potential economic sources of metals (e.g., gold, iron, or copper) or industrial minerals (e.g., cement rock or ceramic clay). The mineral content and physical characteristics are helpful in evaluating the size and extent of mineralization. They may also provide clues about the geologic processes that created a deposit. These conclusions can help determine where else the staff might look in their study areas to locate similar types of deposits.

Contributions to Environmental Health Issues

Some elements and minerals that occur naturally in our environment can have harmful health effects. For example, the asbestos group of minerals occurs in a number of the widely distributed rock types in California. Asbestos minerals used in some manufactured products are known to cause serious respiratory diseases. However, the circumstances are complex.

When some asbestos-bearing rocks are crushed and used in construction, asbestos dust can disperse into the air. In Fiscal Year 1989-90, the State Air Resources Board (ARB) requested several meetings with the DMG geochemist to discuss ARB proposed measures for controlling the effects of using asbestos-containing serpentinite rock in road surfacing. DMG staff also attended a number of workshops held by the ARB Stationary Source Division concerning their proposed sampling and analytical techniques. In these meetings the DMG staff provided information on the nature and occurrence of asbestos minerals and serpentinite rock in California and means of determining asbestos mineral abundance using the microscope. This advice was incorporated into the ARB regulatory rule and into the ARB description of its analytical method for determining asbestos abundance. DMG has been listed in the ARB's advisory to school districts which describes problems arising from the use of asbestos-containing serpentinite and the Division may be contacted for advice on identification.

Because of the potential impact on the California mining industry, DMG has also provided the State Mining and Geology Board with information about the ARB rule and the ARB test method for asbestos in serpentinite rock aggregate. It has also outlined future actions the ARB may take regarding asbestos emissions from mines and construction sites.

The occurrence of crystalline silica in California is another environmental health issue in which DMG's information is useful. Recently there has been growing concern about health consequences of crystalline silica, and the ramifications of possible regulation of such emissions on mining, construction and agricultural operations. The term "crystalline silica" refers to the quartz group of minerals, which has different crystal forms within it, all of which are composed of the compound silicon dioxide. Airborne quartz dust was identified as a source of the respiratory disease, silicosis, over two generations ago. The International Agency for Research on Cancer (IARC) of the World Health Organization has just designated fine-grained crystalline silica as Category 2A (potential carcinogen). They have also recommended further studies to confirm that it is a carcinogen.

Federal guidelines mandate that all products containing 0.1 percent or greater crystalline silica must be labeled in compliance with the Hazard Communication Act.

Crystalline silica is present in many of the mineral commodities produced in California. Examples include perlite (for insulation), bentonite (for oil well drilling) and dolomite (for chemicals and other uses).

DMG staff have begun assembling information on analytical techniques, contents in mineral commodities, and health implications to better respond to requests for information on crystalline silica. Staff have also used the Division's X-ray diffractometer to screen several mineral samples for crystalline silica which were collected during SMARA mineral resource investigations. Depending upon future regulatory developments, such analytical work may become important in evaluating the economic viability of many types of mineral deposits.

Future Applications of DMG's Geochemical Expertise to Environmental Health

DMG receives a number of requests each year from individuals, industry, and government agencies for information on the abundance and distribution of minerals and trace elements of environmental concern in California (for example, asbestos minerals, crystalline silica, radon, mercury, lead and arsenic). As the State's geological survey, DMG has a better understanding of the distribution of these naturally occurring materials than any other provider of information. The DMG geochemical expertise also can provide insights on the behavior of these materials (mobility, solubility, etc.) as they move within the environment, as well as the analytical techniques to detect them.

DMG's responses to these requests are often limited to providing data from old mineral commodity reports that were not originally intended to answer these types of questions. Future studies could be undertaken within the DMG geochemistry program to establish a better data base to use in answering these inquiries, if funding were available for such studies.

Improving DMG's Information Base on Mineral Resources

The Granite Rock Company's Arthur R. Wilson Quarry, San Benito County, formerly known as the Logan Quarry, is in Santa Cruz Mountains about 7 miles east of Watsonville. It is reportedly the largest stone quarry west of Texas, and for nearly one hundred years it has been producing crushed stone aggregate materials for the San Francisco Bay region. The 760-ton mobile crushing plant shown here can be operated by one person and is capable of moving at 38 feet per minute. The Wilson Quarry is bounded on the northeast by the San Andreas fault zone, which has broken the rock so blasting is not routinely required. *(Photo by C.T. Higgins.)*

California is regularly ranked first or second among the states in the production of non-fuel mineral commodities. In 1989, the state's mineral economy approached 3 billion dollars. California's mineral industries provide essential materials to manufacturing, construction and agriculture. The state produces almost one billion tons of crushed stone, sand, and gravel for construction aggregate and is the nation's largest producer of borates, rare earth elements, and diatomite. California is also a significant producer of gold, gypsum, limestone, and decorative rock and is considered to have the most diversified mineral industry in the United States.

Since 1880, DMG has been the focal point for mineral information in the State of California. The Minerals Resource Appraisal Project (MRAP) and the Surface Mining and Reclamation Act (SMARA) mineral resource classification staffs are responsible for acquiring and managing this information. The SMARA and MRAP staffs develop information on known mineral deposits; areas which may be favorable for new mineral development; and locations of current mineral production. DMG publishes maps and reports that describe mines and mineral deposits. MRAP conducts mineral commodity studies, critiques federal mineral survey reports and comments on federal land withdrawal proposals for Wilderness Study Areas. The SMARA staff provide State and local government agencies with information needed to regulate land-use decisions. DMG also responds to numerous requests from the public for mineral resource information.

MRAP maintains extensive files on mines and mineral prospects in California. The project identified 1,132 operations in its 1989 active mines inventory. This information is important to assure that local governments are requiring active mines to submit acceptable plans for post-mining reclamation as required by SMARA. In addition to the data on active mines which are collected biannually, over the years the DMG staff have developed a paper file containing about 10,000 mineral property reports on inactive mines and prospects. These reports are important in mineral exploration and land-use planning.

Several years ago, it became apparent to the Division staff and others who rely on data from the MRAP paper files, that these materials were difficult to use and to maintain. A new data base known as MINEFILE.DBF (Data Base File) was initiated. As part of this process, 10,000 mineral property reports are now being edited in preparation for entry into the system. More than half have been cross-indexed into the computer file. All of California's mines and significant prospects will eventually be located and identified more accurately than presently possible.

The MINEFILE computer data base stores information on the name, location, ownership, regulatory status, employment, mine size and basic geology of the entries. Paper files may contain maps and more detailed information. Used in combination, this data management system will be very powerful. Local government agencies will be able to use their own personal computers to track active mines and to retrieve data using MINEFILE.DBF. Some agencies have developed compatible data systems.

Collaboration with the U.S. Bureau of Mines to Improve the Mineral Files in California

For over a decade the U.S. Bureau of Mines (USBM) has maintained a large, nationwide, mineral property file called the Mineral Industry Location System (MILS). It contains more than 30,000 mine entries from throughout the United States. The USBM felt that the California section of their file needed to be upgraded. In July 1989, the USBM requested that DMG join in updating and improving the MILS data base. This effort began with a two year project to address the data from southern California including Imperial, Riverside, San Bernardino, Kern, Inyo and Mono counties. Southern California was given first attention because of major pending land-use decisions in the desert region. Federal legislation has proposed large tracts to be earmarked for inclusion in national parks, wilderness areas and military installations in the desert, one of the most highly mineralized regions of the nation. Easy access files are vital in providing timely resource information. The USBM recently converted some of its mainframe data files to be compatible with DMG.

The task of merging the State and Federal data files is daunting. It is estimated that there will be 8,000 southern California mine records when the data are integrated. There are about 3,000 entries in San Bernardino County alone.

The USBM's role is to upgrade the southern California MILS file by reviewing relevant literature to verify and expand files. After this federal editing, DMG will compare the USBM files with its own upgraded state entries and an integrated set of records will be prepared.

Benefits of State and Federal Collaboration

California's collaboration with the Bureau is becoming a model for the rest of the country. The southern California file will be identical for both the State and federal governments and the non-proprietary sections of either can be accessed directly by outside users. All parties can have confidence they are using the best information possible in one single, effective search. The computer index will permit all users to conveniently employ the DMG paper files of mineral property reports for supplementary information. The merger of the MINEFILE and MILS data bases for the entire State is the goal.

The Mesquite Mine, Imperial County, is adjacent to the southernmost part of the Chocolate Mountains. Gold was discovered and mined in this desert region during the 1800s and early 1900s. In about 1980, Gold Fields Mining Corporation begin a concerted exploration and development program at Mesquite, which has made the Mesquite Mine one of California's largest gold producers. *(Photo by C.T. Higgins.)*

The Randsburg Quarry, Kern County, is near the historic mining town of Randsburg (Johannesburg), about 40 miles northeast of Mojave on U.S. Highway 395. Gray schitose metamorphic rock is quarried here for use as decorative flagstone. Flagstone and crushed decorative rock products have become important mineral commodities in California. Flagstone is often transported hundreds of miles and sells for as much as $200 per ton. The worker shown here will place these recently quarried rock slabs on wooden pallets. The pallets of rock will then be hauled to urban areas for use in building construction and landscaping. California has dozens of small decorative rock quarries, and many of these are in the Mojave Desert. Brightly colored, crushed, and screened volcanic, carbonate, and granitic rock products from these small quarries are used throughout the State. *(Photo by J.S. Rapp.)*

The closer working relationship between the State and federal staffs can lead to collaborations on other projects in the future. A joint publication summarizing mineral information is being planned. Improved safety and environmental quality can also be facilitated. With more accurate locations and more efficient data management, it will be possible to locate old abandoned mining shafts that should be field-checked to assure that they are not lethal traps for people or wildlife. Better information on abandoned mines will also locate sites to be checked for detrimental environmental effects.

In summary, the collaboration between the USBM and DMG in merging and upgrading their mine data files is a rewarding experience for both agencies. DMG will continue to explore future opportunities of this kind.

CONCLUSIONS

DMG is committed to addressing the evolving information needs of California. During 1989-90, the experience of the response to Loma Prieta has provided new insights for planning DMG efforts after future major earthquakes. Feedback has been acquired on the effectiveness of DMG landslide hazard identification and Alquist-Priolo active fault mapping that indicates these efforts can be enhanced by drawing greater user and public attention to the mapping products. DMG geochemical expertise is assisting other state agencies concerned with certain minerals which can affect health. Mine and mineral deposit files are being automated, and the accuracy of their contents verified, so that this information can be more efficiently retrieved.

It is hoped that this report will stimulate suggestions to DMG regarding additional ways in which we can serve the citizens of California during the administration of our programs. Please send comments and suggestions to the address below:

California State Geologist
Department of Conservation
DIVISION OF MINES AND GEOLOGY
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By Greene, H.G., Kennedy, M.P., and others, 1989
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CMM004 ..... $15.00

CALIFORNIA CONTINENTAL MARGIN GEOLOGIC MAP SERIES (AREA 6 OF 7) NORTH-CENTRAL AREA (Four sheets)
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B 208 ..... $10.00

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By Hable, R.S., and others, 1988
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CLASSIFICATION OF SAND AND GRAVEL RESOURCE AREAS, SAUGUS-NEWHALL-PALMDALE PRODUCTION-CONSUMPTION REGION (LOS ANGELES COUNTY, CALIFORNIA)
By Joseph, S.E., and others, 1964
SR 143 (PART V) $8.00

CLASSIFICATION OF SAND AND GRAVEL RESOURCE AREAS, CLAREMONT-UPLAND PRODUCTION-CONSUMPTION REGION (LOS ANGELES AND SAN BERNARDINO COUNTIES, CALIFORNIA)
By Cole, J.W., 1988
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MINERAL LAND CLASSIFICATION: AGGREGATE MATERIALS IN THE SOUTH SAN FRANCISCO BAY PRODUCTION-CONSUMPTION REGION (ALAMEDA, CONTRA COSTA, SAN FRANCISCO, AND SAN MATEO COUNTIES, CALIFORNIA)
By Stinson, M.C., 1988
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By Cole, J. W., and Fuller, D.R., and others, 1988
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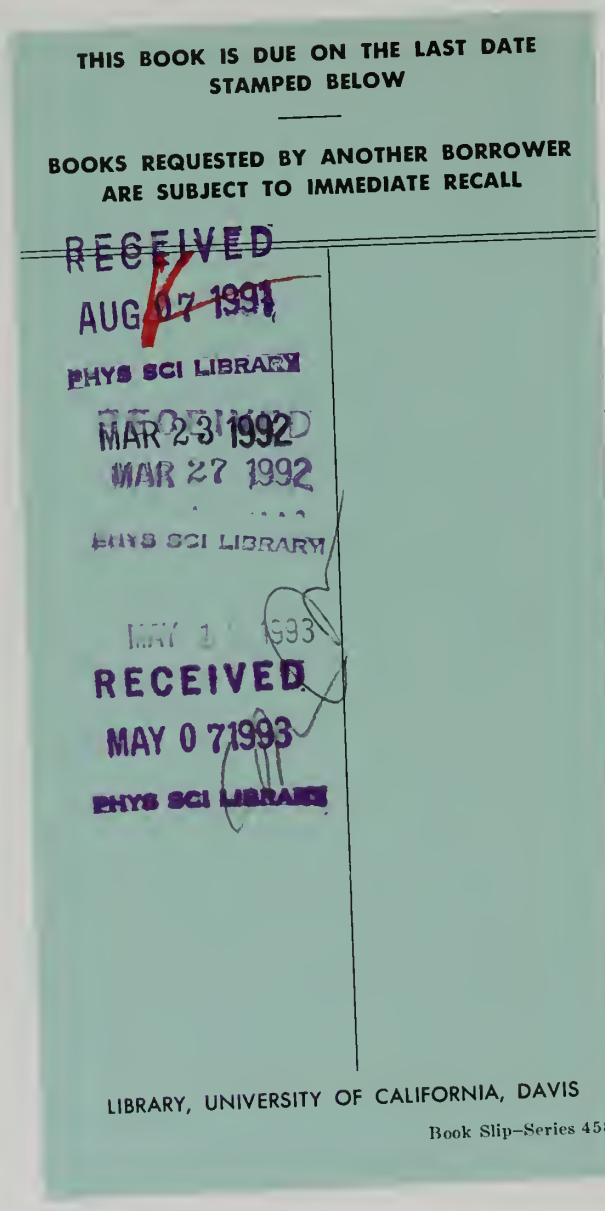
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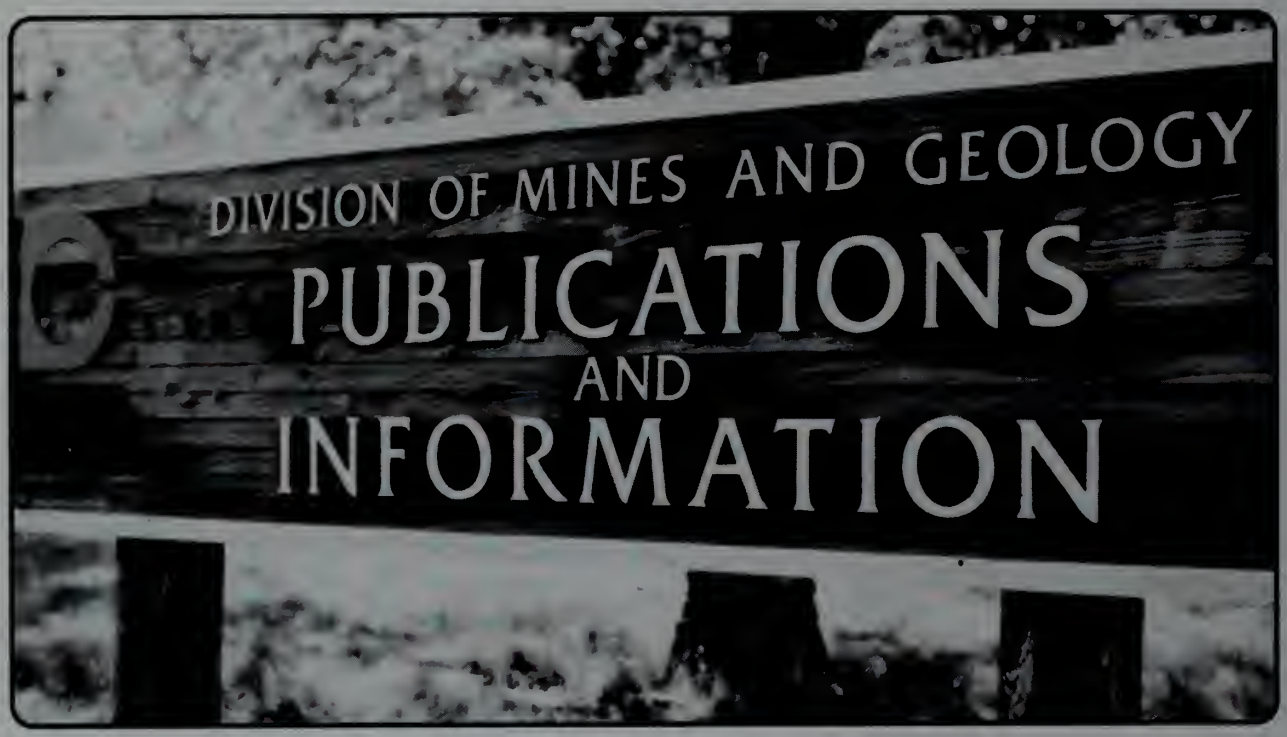

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